ALTERNATIVES TO METHYL BROMIDE FOR WEED CONTROL

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Abstract

The use of methyl bromide as a broad-spectrum soil fumigant has contributed significantly to the control of weeds and soilborne plant pathogens in vegetable production and has served as a "stand alone" weed control tactic in Florida, U.S.A. for many years. The pending loss of this biocide due to environmental issues, has created a need for alternative weed control measures, particularly for minor crops, such as tomato, pepper, and strawberry, for which there are few chemical herbicides registered for use. Losses in fresh market tomatoes in Florida due to weed pressure, with methyl bromide available, have been estimated at more than US$291 million (Bridges, 1992). In the absence of methyl bromide, these losses could increase substantially and represent an area of great concern to vegetable producers. Alternative soil disinfestation methods have been tested in several locations throughout Florida and several methods have provided adequate control of some pathogens and weeds, to date there is no single universal replacement for methyl bromide. Yellow and purple nutsedge have been the focus of several studies and are the most significant weed problems facing growers immediately after cessation of methyl bromide use. However, a greater diversity of weed problems is expected to develop without the broad-spectrum activity of methyl bromide. Studies were conducted to identify what weed problems arise with the use of alternative soil disinfestation practices and biological control agents for these target weeds sought and developed.

1. Introduction

The vegetable industry in Florida, U.S.A. during the 1997-98 season was worth more than US$1.6 billion, covering to approximately 131,900 ha. The bell pepper crop totaled more than US$272 million and the tomato crop was worth US$473 million (Florida Agricultural Statistics, 1999). In 1998, ninety-five percent of all tomato acreage was treated with methyl bromide with an application of more than 2,700 metric tons. In pepper, 1400 metric tons of methyl bromide were used in 1998 (National Agricultural Statistical Service, 1999). In the absence of methyl bromide, increased losses due to weeds are a major concern to growers. The limited registration of efficacious herbicides for use in tomato, pepper, and strawberry will necessitate the use of an integrated approach to weed management (Colvin, 1998).

2. Alternative weed control measures

2.1. Soil solarization

The effects of soil solarization on weed control have been studied intensively in many locations throughout the world. Several weed species have been reported to be controlled by this method, including many of the weed problems that are considered to be of greatest importance in Florida vegetable production systems. Annual weeds that occur in these production systems that are reported as being controlled by solarization include *Digitaria sanguinalis*, *Commelina communis*, *Amaranthus* spp., *Stellaria media*, *Echinochloa crus-galli*, and *Eleucine indica*. Weeds that occur in Florida vegetable production fields that are partially or not controlled by solarization include *Portulaca oleracea*, *Conyza canadensis*, *Cynodon dactylon*, *Sorghum halepense*, *Cyperus esculentus*, and *C. rotundus* (Stapleton and DeVay, 1995). Studies by Locascio *et al.* (1999) showed that soil solarization for 8-10 weeks provided excellent control of nutsedge at two strawberry production sites. Due to the variability in reported results on the effects of solarization on weed species, several tests were conducted in commercial fields in south Florida to determine efficacy of the method in the local production area. Soil solarization experiments were conducted in several locations, including two commercial farms, one experimental farm, and one organic farm. Where possible, tests were conducted over a two-year period. Treatments included soil solarization, solarization combined with biosolids compost, and solarization after deep disking. All treatments utilizing solarization resulted in less than one nutsedge plant/ m^2 emerging through the plastic. In the same trials, control of *Portulaca oleracea* was highly variable. In two test locations with high *Portulaca* density, control achieved using solarization was not comparable to that resulting from treatment with methyl bromide, but in a third location, solarization was as effective at controlling this weed as methyl bromide. In sites with weed grasses, solarization failed to control bermudagrass (*Cynodon dactylon*), goosegrass (*Eleusine indica*), and large crabgrass (*Digitaria sanguinalis*), although control was improved slightly with the implementation of deep disking prior to application of the solarization plastic (unpublished data).

2.2. Alternative fumigants and chemical herbicides

Alternative fumigants that have been tested in Florida for the production of tomatoes, peppers, and strawberries include metam sodium, chloropicrin, 1,3-dichloropropene (1,3-D), and dazomet. Several of these alternative fumigants have been tested in combination with one another and with other chemical herbicides. Control of nutsedge has been the focus of many of these tests. In small-scale field tests, control of nutsedge in strawberry using combinations of 1,3-D, metam sodium, chloropicrin, and the herbicide napropamide did not provide nutsedge control comparable to that achieved using methyl bromide. Solarization and solarization combined with dazomet and metam sodium and chloropicrin were effective in controlling nutsedge emergence through plastic, but did not prevent nutsedge from growing under the plastic (Locascio *et al.*, 1999). Treatments in which the herbicide pebulate has been used in combination with metam sodium, dazomet, or chloropicrin have provided nutsedge control that is comparable to methyl bromide (Locascio *et al.*, 1997), but this herbicide is not useful in pepper production. Combinations of 1,3-D, napropamid, and metam sodium tested in large-scale pepper production fields were variable in efficacy of weed control (unpublished data). The combination of 1,3-D (154 L/ha or 206 L/ha), chloropicrin, and napropamide provided control of nutsedge, with <1 plant emerging through the plastic per m^2. Purslane and pigweed were not controlled with the lower rate of 1,3-D in the combination. In a separate study, the combination of 1,3-D (206 L/ha or 154 L/ha) and metam sodium resulted in an average of 1 nutsedge plant/m^2 and approximately 4 nutsedge plants/m^2 in the high and low rates of 1,3-D respectively. A similar level of control was achieved with the application of 1,3-D at the 154 L/ha rate combined with napropamide.

2.3. Biological control agents

The variability in weed control efficacy by alternative soil disinfestation methods, limited registration of chemical herbicides for use in vegetable production, and concerns of worker safety and environmental impact of alternative fumigants created a need for biologically based weed control alternatives. The use of fungi as mycoherbicides, in which a fungus is applied in an inundative manner to control a target weed, has been established as a viable weed control measure (Rosskopf *et al.*, 1999). The data compiled on weed control using alternative soil disinfestation practices were used to choose target weeds for development of biological control agents.

2.3.1. Pigweed biological control

The fungus, *Phomopsis amaranthicola* (Rosskopf *et al.*, 1999), was determined to be an effective pathogen on a variety of *Amaranthus* spp. The host range of the fungus was tested using a centrifugal phylogenetic scheme with *Amaranthus hybridus* as the focal plant. Thirty-three accessions belonging to 22 species of *Amaranthus* and 56 plant species outside of the genus were tested for susceptibility to the fungus. *P. amaranthicola* was highly virulent on several species within the genus *Amaranthus* and was not pathogenic on any species outside of the genus. Field trials were conducted using *P. amaranthicola* conidia at two concentrations and mycelial suspensions applied once or twice. Species tested in the field included *Amaranthus hybridus, A. lividus, A. viridus, A. retroflexus, A. spinosus*, and a triazine-resistant accession of *A. hybridus*. Application of the highest concentration of conidia (6 x 10^7 conidia/ml) resulted in the most effective control of the weeds, ie. 100% mortality occurred in inoculated plots 25 days before uninoculated plots. The latter, which were not protected with a fungicide, were infected with secondary inoculum produced on the fungus-treated plants (Rosskopf, 1997). The fungus is currently being tested for compatibility with pesticides that are tank mixed and for parameters necessary for large-scale inoculum production.

2.3.2. Nutsedge biological control

A fungus identified as *Dactylaria higginsii* (Luttrell) M.B. Ellis was isolated from diseased purple nutsedge in 1994. The isolate was highly pathogenic to purple (*Cyperus rotundus*) and yellow nutsedge (*C. esculentus*), as well as globe sedge (*C. globulosus*), annual sedge (*C. compressus*), rice flatsedge (*C. iria*), and green kyllinga (*Kyllinga brevifolia*). Inoculation of purple nutsedge with *D. higginsii* conidial suspensions resulted in significant reductions in shoot numbers, shoot dry weight, and tuber dry weight. The fungus was tested against field populations of purple nutsedge. Three post-emergence applications resulted in >90% mortality of purple nutsedge, including significant reductions in tuber numbers produced. In greenhouse studies, a suspension of 10^6 conidia/ml reduced nutsedge competition so that tomato yields from these treatments were equal to that of the weed-free control (Kadir *et al.*, 2000). Collaborative agreements are being developed to commercialize this mycoherbicide. Laboratory and field trials are underway to determine the compatibility of this fungus with post-emergent pesticide applications.

2.3.3. Portulaca biological control

The effects of competition from *Portulaca* in Florida tomato, pepper, and strawberry production are not known. While the weed is found throughout these production areas, its impact on crop development and fruit yields has not been established. These studies are ongoing. Naturally occurring epidemics of a disease caused by *Dichotomophthora portulacae* are common throughout vegetable production areas in Florida (personal observation) as well as in several other locations throughout the world. Attempts to develop this fungus as a biological control agent for *Portulaca* in New York were discontinued due to low humidity during the summer production season (Klisiewicz, 1985). The unformulated fungus is able to cause infection in temperatures from 15-33°C, with symptoms developing within 48 hours of inoculation. While this agent showed excellent promise as a biological control agent, it was not pursued at that time. The current studies with this pathogen system include host-range testing of the local isolates, optimization of culturing procedures and field testing of the organism on native *Portulaca oleracea* populations.

2.3.4. Biological control of grass weeds

Three fungi native to Florida, one species of *Dreschlera* and two species of *Exserohilum*, were isolated from large crabgrass, crowfootgrass, and johnsongrass respectively. In greenhouse trials, these pathogens killed the following eight grasses: bermudagrass, large crabgrass, crowfootgrass, guineagrass, johnsongrass, southern sandbur, Texas panicum, and yellow foxtail, when used in combination or as single-isolate suspensions. All grasses were highly susceptible (disease severity ranging from 82-100%) to the individual pathogens as well as a mixture of all three pathogens. In field trials, the three pathogens alone and in combination were most effective in causing plant mortality to large crabgrass, crowfootgrass, johnsongrass, guineagrass, southern sandbur, Texas panicum, and yellow foxtail when applied in an oil emulsion (Chandramohan, 1999). Current research with this grass pathogen system includes reformulation of the most promising isolates for use in organic vegetable and citrus crops and the effects of the fungi on grass competition in tomato and pepper.

3. Conclusion

Weed control without the use of methyl bromide will present an important challenge to vegetable growers in Florida. The availability of biological control agents for specific weed problems can greatly enhance the ability to develop integrated weed management strategies for use in vegetable production. The implementation of these programs will require more in-depth knowledge of particular weed problems at specific sites. As the number of registered biological control agents for weeds increases, their use can be tailored to these specific needs. Information concerning the composition of weed populations in individual production areas can be used to combine multiple biological control agents and cultural and chemical control measures to provide a system that will lead to effective weed management.

The slow pace of introduction of commercially available weed biological control agents has greatly hampered efforts to integrate effective organisms into a weed management program. Organism-specific research is required to develop methods of inoculum production that are cost effective and result in a consistent, efficacious product. This effort often requires industrial collaboration that is lacking due to the limited market potential for many agents. The cost of registration of new biologically based pesticides, without a large guaranteed market, makes it difficult to obtain industrial sponsorship. As more chemical herbicides are found as soil and water contaminants, herbicide-resistant weed populations become more common and problematic, fewer new chemical herbicides are discovered, and if public acceptance of transgenic, herbicide-tolerant crops becomes more of an issue, it is anticipated that interest in biological control agents will be increased further within the agricultural pesticide industry.

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